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ERP SYSTEMS IMPLEMENTATION IN COMPLEX ORGANIZATIONS

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ABSTRACT

ERP (Enterprise Resource Planning) systems implementation is a great organizational change, which many times does not reach the desired results. This paper proposes to help understand this implementation, considering that the knowledge of change and evolution processes in organizations may lead to other aspects to be considered, assisting in the identification of the most appropriate actions, restrictions and items that may help sustain the change. It proposes a complex organizational reference model to contribute understanding of the implementation process. Research results show that the concepts proposed in this model – subsystems, emergence, behavior attractors and complexity limits – apply to organizations and contribute to the understanding of the changes triggered by an ERP system implementation. Among other contributions, this work shows the importance of potential generation for change, the relationship among the behavior attractor and competitive advantages gained, and organizational systems maturity considerations.

Keywords: Complex Systems, Organizational Change, Organizational Evolution, ERP Systems Implementation, Systemic Approach.

1 INTRODUCTION

Enterprise Resource Planning (ERP) systems are information systems that

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integrate all business information in organizations, providing processes control and unique information flow. Usually, they are sold as software packages, which implement the best practices in the market. Organizations that implement them have to choose between implementing these practices and changing current business processes; or customizing the software to adapt to current business processes (MENDES & FILHO, 2002; ZWICKER & SOUZA, 2003).

Some organizations are successful in implementing ERP systems and achieving relevant process improvement, but others encounter various barriers, especially related to resistance to change (MENDES & FILHO, 2002; ZWICKER & SOUZA, 2003, SANTOS JUNIOR et al., 2005). Each case has its specific reasons for not achieving successful ERP implementations, but some studies point to the fact that this implementation is actually a great organizational change (SOUZA & ZWICKER, 2003; SACCOL et al., 2003) and in most cases these changes do not reach the desired results (SENGE et al., 1999).

To Senge et al. (1999), all kinds of growth in the nature come from the interaction between processes that enhance growth and processes that inhibit it. When growth stops prematurely, before the organism reaches its potential, it is because it found restrictions that could have been circumvented and are not inevitable. According to the author, these concepts show that, “most strategies for change may be destined to fail from the beginning”, when leaders do not focus on the potential for growth. The focus should be mainly on the limiting procedures that could delay or prevent a change.

Dooley & Van de Ven (1999) confirm this need for knowledge of organizational behavior patterns. For them, when these generating mechanisms are discovered, it is possible to postulate how changes in specific organizational variables affect the dynamics of the system. This knowledge can help us explain the past, predict the future and develop intervention strategies.

Although ERP systems have been used and improved since the 1970s, the technology is still evolving and researchers still need to understand the actual impact of the ERP system implementation on organizational alignment, learning, infrastructure, outsourcing, customization and competitive advantage (CHUNG & SNYDER, 2004). This is evidence that organizational models may help understand the relevant elements in ERP systems implementations and provide better strategies for successful implementations.

The changes necessary to transform the enterprise in an integrated organization, through these implementations, generate diverse complex transformations in behavioral and structural aspects (JESUS & OLIVEIRA, 2007). There are plenty of models that describe organizational structures and dynamics that could be applied to ERP systems implementations. However, it is important to observe that organizations are human systems in which multiple agents interact at the same time (STERMAN, 2000). Considering complex social systems theory to understand organizational processes may enable the creation of new organizational forms and changes in strategic thought (MITLETON-KELLY, 2003).

The deployment of an ERP system is a process that has been considered critical and that often does not generate the expected results. If the knowledge of behavioral patterns could help explain the past, predict the future and develop intervention

strategies, it is possible that knowledge of the processes of change and evolution of organizations can help in the identification of the important elements of the deployment of ERP systems.

So, the general objective of this study is to analyze the implementation of ERP systems based on a proposal for a model of organizational change. It presents a study based on the complexity theory to understand ERP systems implementation. A systemic approach is used as the methodology for model creation. Organizational models are explored to create a basis where organizations can be seen as complex systems changed by a large-scale information system implementation. Hence, this paper presents an application of a systemic approach to an organizational study, a summary of some important organizational change theories, considerations of organizations as complex systems, and a model, applied to ERP implementations, which represents organizationally complex structure and behavior.

2 RESEARCH QUESTION

According to the objectives and justification presented, this research aims at responding to the following question: *What are the relevant aspects in the process of organizational changes generated by the implementation of ERP systems?*

3 ORGANIZATIONAL CHANGE

Van de Ven & Poole (1995) state that change is a kind of event, an empirical observation over time of some differences in an organizational entity's form, quality or state. Mintzberg & Wesley (1992) have classified various types of organizational changes based on four different approaches: contents and levels, means and processes; episodes and stages and sequences and patterns, as summarized below.

Contents and levels

Contents and levels of change define various contents in organizational change at different levels of abstraction. Mintzberg & Wesley (1992) have shown that change may happen in an organization from a wide and conceptual form to a specific and concrete form. These changes may occur in two forms of conceptual change: organizational state (culture, structure, systems and people) or organizational strategy (vision, position, programs and facilities). These change contents may occur at different levels. It may be a revolutionary change, which affects the whole organization; a fragmented change, which changes various elements in an independent way; a focused change, which happens at all levels of one organizational part; or an isolated change that refers to a specific change.

Means and processes

Means and processes of change describe the means in which change emerges and their related processes. The focus of this aspect of change is on identifying how it emerges and how it is managed. It might be one of the most studied aspects in the bibliography, because knowing change processes gives individuals a basis to create strategies to deal with change and to take adequate actions, at the right time

(FONTANA & IAROZINSKI NETO, 2005).

Means of change may be classified in first and second order changes. First order changes are those seen as incremental, as local adaptations of the organizational structure. For example, price-changing rules, new products launches, changes in investments on research and development and advertisements. Second order changes are those that represent changes on base-structure. For example, changes in the organization's form or design (ETHIRAJ & LEVINTHAL, 2004).

Other authors classify three different means of change. Mintzberg & Wesley (1992), for example, have identified change as being procedural planning (deliberated and deductive change), visionary leadership (informal, guided by a leader) and learning (informal and emergent). Blumenthal & Haspeslagh (1994) have shown that change can be seen as operational improvement (to improve efficiency), strategic transformation (to gain a competitive advantage), and corporative self renewal (learning to anticipate change and deal with it). Similarly, Kerber & Buono (2005) have classified change means in three forms: direct (guided by high management), planned (arises in any level to ease resistance) and directed (which emerges from inside the organization).

Episodes and stages

Episodes and stages represent particular episodes of change and stages by which the organization goes through to get out of an established cycle. Mintzberg & Westley (1992) claim that change usually takes the form of episodes (distinct periods in which a number of changes happen), which are the result of external or internal events. Such episodes can be changes (more revolutionary, leading the organization to other positions) or revitalizations (slower and adaptive, developed in small steps).

Sequences and patterns

Sequences and patterns of change identify patterns of transformations observed over time. The different patterns that can be seen over time, according to Mintzberg & Westley (1992) are periodic impacts (long periods of stability interrupted by revolutions), oscillating changes (convergence and divergence around different positions), life cycles (development sequence) and regular process (marked by strategic vision and inductive learning, usually occurring in academic environments).

Authors in the bibliography describe the pattern of an organizations' life cycle more intensively. One of the classic models of organizational changes is from Greiner (1994). Greiner divided the growth curve of organizations in five stages, which are defined by factors: management focus, organizational structure, management style, system control and reward management. Greiner (1994) states that each stage is characterized by a period of evolution and ends with a period of revolution, or crisis. This author uses the word "evolution" to describe periods of growth, when no major change occurs in the practice of the organization; and the term "revolution" to describe periods of intense disorder. Facing this crisis leads the organization to the next stage, when new organizational practices must be adopted to adapt to the new phase. There is also a sixth stage of growth defined by Greiner, which features a network of organizations (ROCHA, 2002).

Other models are found in the bibliography, always featuring the evolutionary cycle of the organization in stages, defined by different organizational attributes. Table

1 summarizes other authors and the main features.

Table 1 - Organizational Evolutions Stage-based Models

Author	Stages in the model	Stages Characterization
Churchill & Lewis (1983)	5 (Existence, Survival, Success, Take-off, Resources, Maturity)	Management style, organizational structure, broadness of formal systems, main strategy and owner-business relationship.
Sibbet (2003)	7 (Birth, Expansion, Specialization, Institutionalization, Regeneration, Co-creation, Transformation)	Organization intentions and realities.
Rooke & Torbert (1998)	8 (Conceptions, Investments, Incorporation, Experiments, Systematic Productivity, Collaborative Research, Fundamental Community, Liberal Disciplines)	CEO (*Chief Executive Officer*) personal development and organizational development.
Montenegro & Barros (1988)	4 (Uncertainness, Accelerated Growth, Regression, Definition)	Objective, structure, processes and dynamism.
Mintzberg & Westley (1992)	5 (Development, Stability, Adaptation, Effort, Revolution)	Types of changes that occur in an organization.
Raposo & Ferreira (1998)	5 (Birth, Expansion, Maturity, Diversification and Decadence)	Age, size, growth rate, structure form, formalization, centralization, tasks/functions.

Considering organizations as complex systems defines new perspectives for organizational model theories. Meyer et al. (2005) have identified that organizations are not systems under equilibrium. They found that change in these systems has non-linear behavior and, moreover, that it is not possible to define that these systems adapt to their environment because the term “adapt” considers a process of equilibrium search, which is not the case of organizations.

Goldspink & Kay (2003) say that modeling organizations as linear systems may lead to two serious problems:

1. Understanding the relationship of macro and micro behavior, in other words, understanding how peoples’ actions generate micro and macro complex organizational behavior and these behaviors may have different properties if compared to peoples’ actions. Or understanding how the macro behaviors interfere in individual behavior;
2. Explaining dynamic complex behavior, auto-organizations and variations generated by changing environments.

4 ORGANIZATIONS AS COMPLEX SYSTEMS

McCathy et al. (2000) have identified that manufacturing organizations are indeed complex adaptive systems because "they consist of an integrated assembly of interacting elements, designed to carry out cooperatively a predetermined objective, which is the transformation of raw material into marketable products".

According to Iarozinski Neto (1996), a system should be considered complex when it is made of groups of elements with different functions and behaviors, which apply to the definition above. They are in constant evolution and are influenced by events that cannot be foreseen with certainty. The information about the state of these elements cannot be completely known, and the elements are related by a great variety of inter-relationships.

Complex systems present some peculiar characteristics summarily described below:

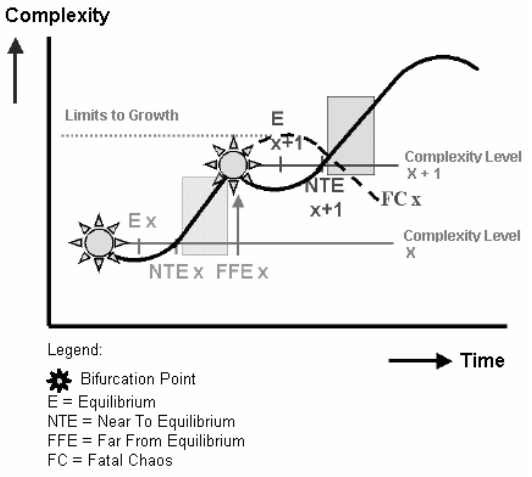
- **Auto-organization and emergence:** auto-organization may be described as the spontaneous union of a group to accomplish a task or a purpose. The group decides what to do, how to do it and when to do it. Nobody outside this group directs these activities. The emergence of human systems creates non-reversible ideas, relationships and organizational shapes, which become part of the individuals' and the institutions' history. That is why they interfere in the evolution of these entities. Organizational learning, for example, is an emergent property (MITLETON-KELLY, 2003);
- **Connectivity and Environment:** connectivity and interdependence mean that one element (or group) decision or action may affect related elements and systems. The degree of connectivity determines the net of relationships and transferring of information and knowledge, and it is an essential element in the feedback process. Nevertheless, the viable connections that can be held are limited and the information (that comes from connections) each individual may deal with is also limited (MITLETON-KELLY, 2003). Considering the relationship of the system and the environment, Mitleton-Kelly (2003) states that the concept of co-evolution comes from the mutual influence between the elements of the system. In human systems, co-evolution emphasizes the relationship among the entities that co-evolve. According to what was proposed by Meyer et al. (2005), the term "adaptation" is not applicable to complex systems.
- **Non-linearity and feedback:** Organizations are also dynamic and non-linear systems (STERMAN, 2000; LITCHENSTEIN, 2000). Complexity is a characteristic of the behavior in non-linear open systems, its structure form and the construction of its special and temporal space (KNYAZEVA, 2003). Systems dynamics states that complex systems are structurally based on a feedback concept: our current actions define future situations. Because of this feature, organizations are feedback systems (STERMAN, 2000). According to Sterman (2000), actions change the state of the system and people react to reestablish the equilibrium. These actions may generate collateral effects, which are called this because we have limited knowledge of the system. Positive feedback typically generates growth in the system, while negative

feedback does the opposite, searching for balance. However, structures that mix both types, generate diverse behavior.

- **Far-from-equilibrium:** Mitleton-Kelly (2003) states that instability (far-from-equilibrium) happens when a system operates outside of established rules, or outside of the usual ways of working and relating. In this situation, an organization may arrive at a critical point and deteriorate to disorder (moral and productivity loss, etc), or create some new order and organization (find out new ways to work and relate, creating new coherence). There is a third behavior state, which is not stable nor instable, but both simultaneously. This is on the edge of instability. In this state, there is instability in the sense that specific behavior is not predictable in the long term, but there is stability in the qualitative structure to this behavior and short-term results are predictable (STACEY, 1995).
- **Structure and Composition:** According to Mitleton-Kelly (2003), complex systems characteristics tend not to vary independently of scale. They can apply to all systems levels (from an individual to the system as a whole) and to systems on different scales (team, organization, industry, economy, etc). This concept relates to Simon's complex system structure description (IAROZINSKI NETO, 1996). His definition states that complex systems organize on multi-level "hierarchic" structures. All levels are composed of sub-systems groups, which present stability. The frontier in each system may be identified by the intensity of the relationships. This "hierarchy", indeed, has heterarchy characteristics, being multi-level relationship without formal authority among them. Tree structure is also found, being interlinked subsystems, each one with its own tree structure down to the most elementary level.

Changes in a non-linear system are determined by a series of phases, each one of which is governed by an attractor. An attractor is a pattern of behavior to which the system fixes itself. Each phase has specific sets of unique behaviors that exist latently in the original non-linear configuration of the system (FERDIG, 2000).

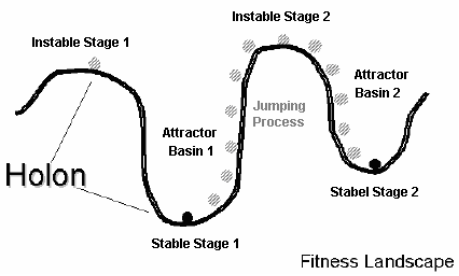
Figure 1 - Discontinuous growth curve of a chaordic system. Adapted from Eiinatten (2003)



Eijnatten (2003) completes the analysis regarding complex systems behavior over time. In his concept, organizations are chaordic systems, that is, systems composed of elements connected in a complex and dynamic form, forming a whole whose behavior is simultaneously unpredictable (chaotic) and standardized (having order). A chaordic system life cycle may be described like this: the system is born or is started, starts to develop and grows until maturity. Then, it reaches a growth limit, from which it might jump to another complexity level, where it starts a new development cycle. From the growth period to maturity a chaordic system goes through a period of relative stability (gray area in Figure 1). When the system arrives near its limit, the system starts to bifurcate and then enters a period of relative instability.

A discontinuous growth curve (Figure 1) may be seen as a sequence of two phases: stable relative stages (E and NTE), in which the system develops linearly through incremental changes; and non stable relative stages (FFE and FC), in which the system changes non-linearly through transformative change or qualitative jumps. Throughout the system chaotic phase, it shows high sensibility dependence on the initial condition (SDIC), or butterfly effect.

Figure 2 - Illustration of a "Fitness Landscape" and the attractor basins. Adapted from Eijnatten (2003).

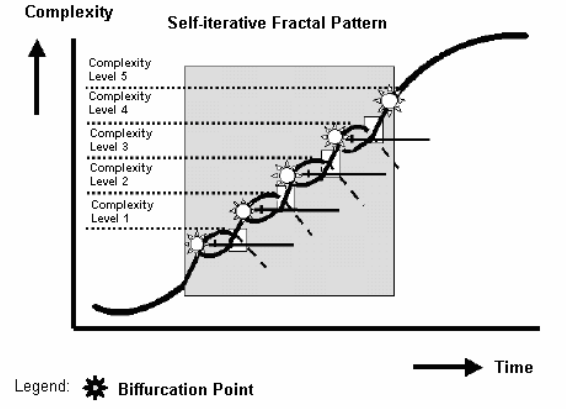


In each one of these states, the system is under the influence of different attractors. An attractor is a condition that forces a chaordic system to repeat a behavior pattern, not always exactly in the same way, but always within specific and clear frontiers. An attractor basin is an area where the attractor can execute its magnetic function attracting any performance level. A new attractor basin represents a new order. A *fitness landscape* is the composition of multiple attractors (and its basins) to which a *holon* can be attracted during its journey (Figure 2). Holons are entities that are simultaneously the whole and a part of the whole. They are autonomous and independent, similar to the definition of autopoietic entities from Maturana & Varela (2001).

Bifurcation points, also called opportunity windows, mark the moment when the holon is under the influence of another attractor basin (entering an instable stage) and

can jump, without external influence, to a stage with greater complexity or dissipate (Figure 1). Even during stable phases, a chaordic system shows discontinuous behavior in the little jumps in gradual changes, which shows the fractal dimension of growth. Gradual change on a macro level may be interpreted as a series of little qualitative jumps in the micro level (Figure 3).

Figure 3 - The fractal dimension of growth in chaordic systems. Adapted from Eiinatten (2003).



During a non-linear change period, the system oscillates between different modes of behavior, as shown in Figure 4. The table shown is called the Chaos Cross by Eijnatten (2003), and occurs when two superior cells are considered the dominant pattern and the inferior cells are considered as the emergent pattern. A successful change in the system is defined as a transition from cell I to cell IV. Other types of change are considered pathological changes, because they do not sustain themselves and should be considered as temporary. During instability phases, chaordic systems are very sensitive, being that little changes in the initial conditions may cause dramatic effects.

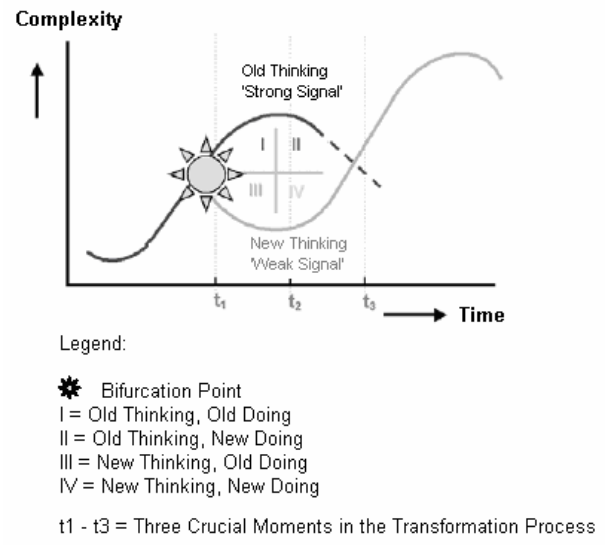
Holling's (2001) theory on ecosystem evolution is similar to Eijnatten's. To Holling there are three properties in a system which determine the shape of the adaptive cycle;

- The system's potential to be open to change (productivity, human relationships, mutations, inventions);
- The system's controllability, which is the degree of linkage among variables and processes related to internal control. This is a measure that reflects control flexibility and rigidity degree;
- The system's adaptive capability, or resilience, which is a measure of its vulnerability to unexpected and unpredictable shocks;

The adaptive cycle passes through four phases, as in Eijnateen's (2003) model.

They are called r, K, Ω and α, and the properties mentioned above gain emphasis differently in each of the phases, thus changing the system's behavior.

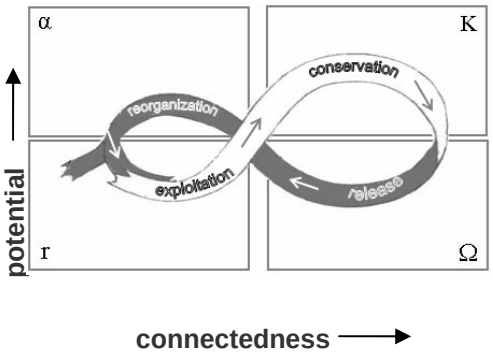
Figure 4 - The Chaos Cross in a non-linear development. Adapted from Eijnatten (2003).



R to K phase is a period when potential grows together with a decadence of productivity and an increase in the system's rigidity. In K to Ω, as the potential grows, slow changes gradually generate a growing vulnerability. Accidents are imminent in this period because they may trigger the liberation of accumulated potential. Phase Ω to α is a period when uncertainty is big, potential is high and controls are weak, allowing new combinations to form. This is when innovations emerge. And finally, these innovations are tested from phase α to r. Some fail, but others survive and adapt to a new growth phase (from r to K). See Figure 5.

According to Holling (2001), one of the main goals of this model is to define where a subsystem is inside its own adaptive cycle. Some actions that would be appropriate in some phases of the cycle may not be in other phases. Knowing where the system is helps defining actions to be taken.

Figure 5 - Adaptive cycle of complex systems, adapted from Holling (2001)



Both authors' studies have shown that there are arguments and approaches to consider organizations as complex adaptive systems, and organizational attractors like shapes that delimitate the systems' trajectory. Even decades ago, Lewin (1965) identified that in social groups there are diverse "forces" (more or less intense) that keep the group in a specific situation (or level, in the phase space), or almost-stationary equilibrium. This concept of group "levels" maintained by forces leads to the attractor's concept seen before. In addition to that, Lewin (1965) still considers that a planned change consists of changing the force field, so that the system level is changed.

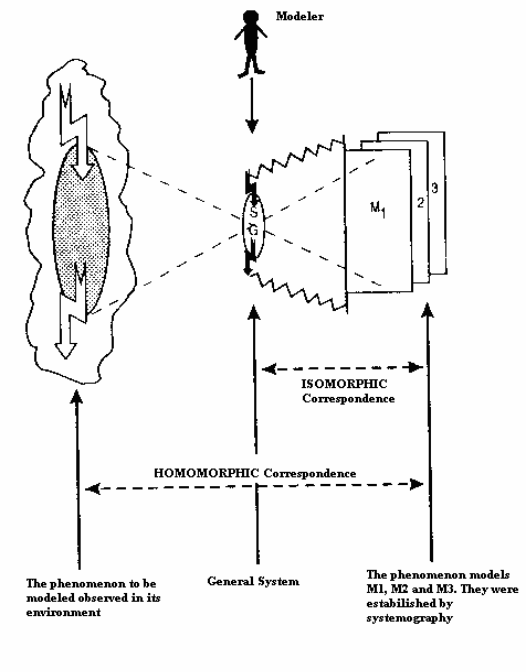
5 METHODOLOGY

This research may be classified as an exploratory study, which, according to Gil (1994), has as its central concern "developing, clarifying and modifying concepts and ideas". It has the objective of formulating problems and hypothesis, which can be researched in future studies. Based on literature, this study aims to answer the research question following the precepts of the systemic approach.

The systemic approach complements the concepts of functionalism and structuralism. It is a methodology that emphasizes organizational phenomena, because it considers not just physical and biological characteristics, but also heterogeneous entities composed of men, machines, product movements, etc. The focus is on the system's dynamism, on inter-relationships and on system-environment relationships (DEMO, 1989).

Le Moigne (1990) defines systemography as the process of creating complex phenomena models. Scientific observation results depend essentially on the observer, who watches reality through a "glass". Reality is identified as a phenomenon. This phenomenon is observed through the glass, which is a general model assigned to the observer's intentions. Isomorphism is used to associate reality to this general model, that is, relating to different entities with similar appearance. Reality is then considered as having the same form (homomorphism) as the phenomenon is seen as complex. From these relations, one is able to create models that represent reality (Figure 6).

Figure 6 - The model creation process defined by Le Moigne (1990)



The procedure to create the model is 1) framing: construction of model M considering isomorphism with a general system; 2) development: documentation of M considering homomorphism with complex phenomena; and 3) interpretation: simulation of the actions over M to anticipate the consequences of the changes in the phenomena. One should model actions, and not things; and consider that the system is under constant interaction with other systems (LE MOIGNE, 1995).

Donnadieu et al. (2003) shows that modeling is the main tool of the systemic approach. It must be done through reality observations considering three aspects: 1) functional aspect, focused on system finalities; 2) structural aspect: describes the system structure emphasizing subsystem relationships; and 3) historical aspect, which observes the evolutionary nature of the system, that is, its history.

This study considers concepts from a systemic approach to define a reference model of organizational change and evolution, applied to ERP systems implementations in the following steps (Figure 7):

1) *Phenomenon Identification:* bibliographical revision to observe elements involved in the process of organizational change and evolution. The main concepts of this research were presented in sections 3 and 4. It considered traditional organizational change theories and change theories based on complexity concepts. The concepts identified in this phenomenon identification were used to build the general system, which is the model that gives basis to reality observation;

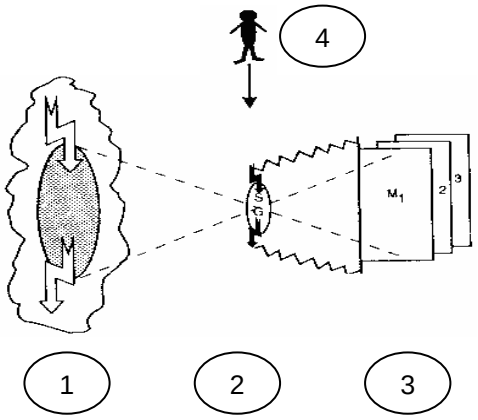
2) *General System Creation:* creation of the reference model, based on bibliographical concepts, under systemic approach directions. This model is presented in section 6 (Organizational Change Reference Model). The three aspects proposed by Donnadieu et al. (2003) – functional, structural and historical – were considered to create a model from the theories analyzed in phenomenon identification;

3) *Reality Observation:* An ERP implementation case study analysis, based on the reference model, so that isomorphic correspondences can be found between the organizational change model and elements in ERP implementation cases. It corresponds to the framing phase in the Le Moigne (1990) model. This reality observation was conducted based on questions (see Section 7) that include elements of the model purposed in the previous step (General System Creation). Twenty nine (29) case studies described in papers were analyzed by one of this papers' authors. For each case, the questions were answered searching for an understanding of the changes generated in the implementation of ERP systems, to identify actions and behaviors related to the subsystems (structure and cognition), and related to the dynamics of change and evolution. These cases originated in diverse countries and were chosen for analysis when they described real ERP system implementation cases with enough detail to be characterized from the reference model point of view. Tables 2 and 3 present the references for the authors of the cases. Section 7 presents a summary of this analysis and further details should be verified FONTANA (2006);

4) *Interpretation:* corresponds to the identification of the contributions coming from the reality understanding model, that is, how the model contributes to the understanding of the changes generated by ERP implementations, presented in Section 7. It corresponds to the development phase proposed by Le Moigne (1990), in which homomorphic correspondences are identified between the model and reality. This interpretation was done by the authors, searching for the elements in the reference model which appeared in the case study descriptions, to apply the concepts of the model in ERP systems implementation context.

5)

Figure 7 – Study's methodology



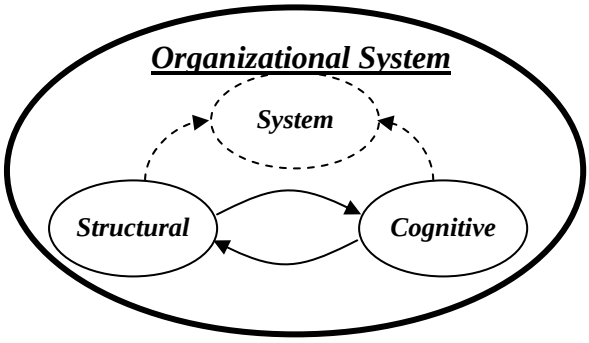
6 ORGANIZATIONAL CHANGE REFERENCE MODEL

Donnadieu et al. (2003), Iarozinski Neto (1996) and Capra (2003) consider three dimensions when studying complex systems, productive systems or live systems. Identifying key elements of the three authors, and keeping in mind the goal of defining the organizational system, the need to define the model under three aspects was identified: structural, functional and evolutionary. The *functional* aspect, as a function or behavior of the system, is determined by its pattern of organization; the *structural* aspect, set by inter-relationships between formal elements that restrict their behavior, and *evolution*, as a vital process of the incorporation of new standards, features or information, which guarantee the development of the system.

The *structural aspect* of an organizational system is composed of two subsystems: structural and cognitive. The structural subsystem includes everything that is formal within the organization, to which investment of time and money is made, that is, in the structure of the organization. Thus, the structure is a subsystem that influences the degree of restriction or freedom of the agents in the system, which connects it with another aspect of the organizational system: the cognitive subsystem. While information travels through the structural subsystem, it is within the cognitive subsystem that it is understood and interpreted. Therefore, these dimensions are closely related.

Cognitive is a subsystem mainly related to human resources, their attitudes, knowledge, mental models and culture. Thoughts can be shared through a higher or lower flow of information between individuals, enabling systemic thinking, mental model shifting, shared vision occurrence and team learning. The extensive use of communication in the interaction and installation of free improvisation (BROWN & EISENHARDT, 1997) as a means of learning, also shows the importance of how the information is handled.

Figure 8 – Organizational System



The dynamics of the relationship between the two subsystems generates the emergent organizational behavior. From the point of view of an observer, behaviors are functions that the system performs to meet their purposes. Each structurally cognitive configuration enables the system to use a set of possible behaviors. In other words, the

behavior is a function of the structure and cognition in the formula: *behavior = f (structure, cognition)* (Figure 8).

This model proposes that every action performed within the organization affects one of the two subsystems: structural or cognitive, because these are the "visible" dimensions in which one can interfere directly. The behavior is the dimension that, although one can not interfere directly, modifies itself over time with the possibilities that the structural and cognitive subsystems generate. To graphically represent the two subsystems and organizational behavior, it is proposed that the structural and the cognitive subsystem constitute a plan, in which an area represents the organizational configuration generated from the perceived need in the environment (Figure 9).

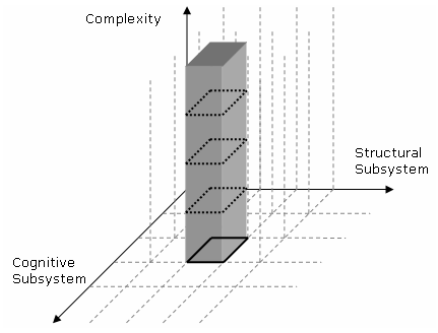
If we consider that the behavior is a function of this plan, it will emerge from the opportunities generated by cognitive and structural subsystems, generating a space of possible behaviors. Depending on the level of the answers offered by the organization to the environment, this space is placed in different locations in the third axis (Figure 9).

If, according to Morin & LeMoigne (2000):

1) Cognitive processes of intelligence of a system is the ability of the system to represent a situation and develop opportunities for adjustment, from which some choices can be made; and
2) For an organization to be smarter, it also needs to be more complex and

the third axis represents the **complexity** of the organizational system. The possible answers an organization can give its environment depend on the level of its ability to interpret demand and choose the best configuration. Because this capacity is related, as seen above, to the complexity of the system, this representation is given to the axis where the organizational behavior is.

Figure 9 - Structural and cognitive plan generate possible behaviors in Complexity axis



The space formed by the displacement of the plan along the complexity axis represents all possible behaviors limited by a certain structure and driven by a specific cognitive system. Depending on the complexity of the organizational system, such behavior is present at a given level of the third axis. This level may be appropriate - or not - to the pressure exerted by the environment. This means that the organizational system has the capacity to understand its environment and develop strategies to respond

accordingly. This capacity level positions the set of possible answers on the vertical axis, for a given structure-cognition configuration.

The area of possible behavior acts, as a strange attractor (FERDIG, 2000), defines the answers of the system and forces it to repeat a pattern of behavior, not always in the same way, but always within specific boundaries (EIJNATTEN, 2003). Specifically, the organizational behavior at any given time is then represented in the form of an area in a plan within the attractor space.

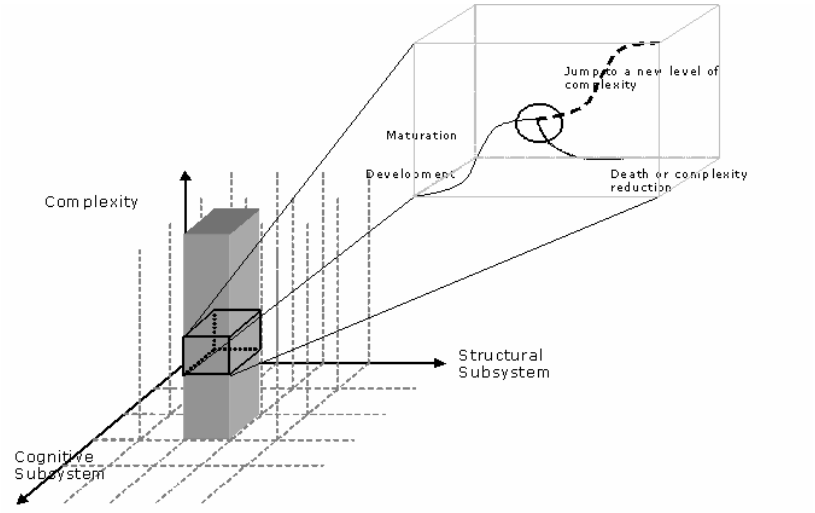
Complex Organization Evolution

Organizations, seen as complex systems, are formed by autonomous entities, interconnected in different ways and at different intensities. They are self-organizing and self-generating entities in higher levels. Their behavior emerges as a result of the non-linearity of its feedback structures and its structures co-evolve with the environment, with the potential to generate a new order after periods of instability.

Periods of instability arise from time to time when the system reaches its limit of complexity. Plotting a parallel to the various organizational evolution models, it is possible to realize that authors define development in terms of stages, and transition from one stage to another is marked by a crisis. Behavior in the next stage is responsible for solving this crisis by generating another one, but some time later,. Punctuated equilibrium theories also define that systems go through long periods of stability, called equilibrium, punctuated by compact periods of qualitative and metamorphic change, or revolution (ROMANELLI & TUSHMAN, 1994; GERSICK, 1991; BEUGELSDIJK et. al, 2002).

In periods of relative stability, the system makes changes that preserve its structure against internal and external disturbances. They do not alter the deep structural and cognitive subsystem, keeping the performance of the organization within specific boundaries, as an attractor. Over time, the fundamental structure of the system tends to collapse because, according Stacey (1995), informal systems move the organization to a fragmented and disordered state. Some of the characteristics of the organization at this stage are of cultural diversity, conflict, weakly shared vision, ambiguity: all elements belonging to the cognitive subsystem.

Figure 10 - Organizational system attractor shift

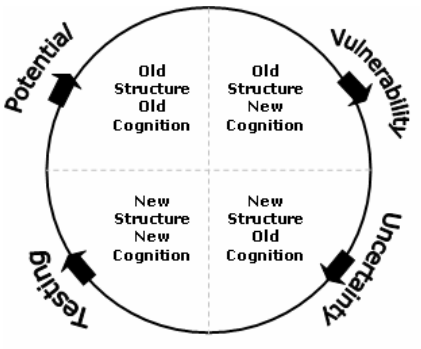


From the moment it enters into a new attractor, the system passes through a life cycle of development and maturation, until it reaches the point of bifurcation, which marks the limit of its complexity. At this point, either the system jumps to a new level of complexity, or it dies (Figure 10). The new level of complexity can be a level below the current level, and it does not necessarily need to kill the system.

This new level of complexity will be characterized by other types of behavior, which must meet a level of efficiency identified by the system as necessary to meet the pressures of the environment. It is important to remember that the processes of perception and interpretation of this need and deployment of the necessary changes occur in the structural and cognitive subsystems.

For the organization to be able to get to another level of complexity, the system goes through four stages through which it slowly adjusts to the new configuration (EIJNATTEN, 2003; HOLLING, 2001). In the first phase, which is called *potential*, the structural and cognitive subsystems are in the old configuration, but there is potential for change. Little by little, new actions start, the cognitive system takes new forms, while the old structure remains. This is the phase of system *vulnerability*, with characteristics similar to the collapse of the fundamental structure defined by Stacey (1995). With a vulnerable system, the cognitive subsystem tends to increase control, returning to the old configuration. Then, considering that the structure is already changing to the new configuration, the period of uncertainty starts. The *uncertainty* phase is characterized by a new structural subsystem and old cognitive subsystems. To allow new combinations to form, control tends to decrease, bringing cognition to the new setup, which is the phase of *testing*, when the innovations are then tested. Some fail, but others survive and fit into a new phase of growth. The system has reached a new level of complexity and will now need to start a new development cycle. Figure 11 shows this process of transition of level of complexity.

Figure 11 - Transition of complexity level



Unlike living beings, which are born with a structure and maintain it until the end of their life cycle; organizations have a structure and it can act over this structure. Organizational structures can be renewed, and therefore the S curve of the growth pattern is within the organizational attractor of possibilities, or within a certain level of complexity. When the limit is reached, the organization has the ability to choose a new structural-cognitive configuration that is appropriate for the new level of complexity. Then a new S cycle restarts for the new attractor.

A system is considered mature when it meets the demands of its environment with a high enough level of complexity for its survival. That is, the organization that is capable of doing what must be done to survive in its environment very well, is considered a mature organization.

Changes in organizational systems

It was observed in the bibliography that an approach to organizational change defines how change can occur in an organization, considering its origin and results that can be generated. Linking the vision of diverse authors together, it is possible to define that organizational change may happen in three different forms: 1) intentionally, imposed by senior management for strategic changes; 2) intentionally, defined internally for operational improvements; or 3) natural, in the form of learning through experience.

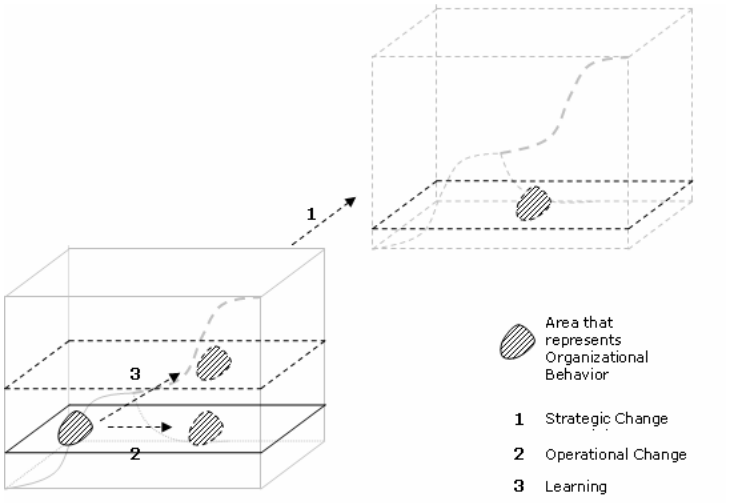
Relating these concepts with the complexity theory seen as applicable to organizations, this study has identified that:

– *Strategic change* creates a new level of organizational complexity, or it changes the position of the attractor of possible behaviors (Figure 12, item 1).

– In *operational change* the organization does not assume a new level of complexity, it just changes the answers for the environment – intentionally – within the existing possibilities in its attractor (Figure 12, item 2).

– *Learning* happens gradually and non-intentionally, with the same attractor, by changing the positioning of the plan where organizational behavior is at a moment (Figure 12, item 3).

Figure 12 - Different types of change applied to the general model



It is important to notice that incremental changes, over time, can lead to a limit of complexity within the attractor and generate the need for a strategic shift, to change the positioning of the range of possible responses to start a new cycle of learning.

7 ERP IMPLEMENTATION STUDY

The ERP implementation study was conducted based on questions that include elements of the model proposed in the previous section. Twenty nine (29) case studies described in papers were analyzed. For each case, questions were answered searching for an understanding of the changes generated in the implementation of ERP systems, to identify actions and behaviors related to the subsystems (structure and cognition). Activities described in the case studies were identified as actions or behaviors. Among the action activities are those where it is possible to identify intentional actions of the organization, both over structural and cognitive subsystems. Under behavior, this study grouped all kinds of perceptions that emerged during the project deployment, and did not derive directly from human action.

First, six questions are asked to identify factors related to the structural and cognitive subsystems. They are:

1. Which actions have been taken on the structural subsystem?
2. Which actions have been taken on the cognitive subsystem?
3. Which behavior arose during the process of implantation in the structural subsystem?

4. Which behavior arose during the process of implantation in the cognitive subsystem?
5. Which behavior emerged after the process of deployment in the structural subsystem?
6. Which behavior emerged after the process of deployment in the cognitive subsystem?

Then, seven more questions were performed with respect to the dynamics of change and evolution in the system during the deployment.

1. Is it possible to identify the influence of the environment and the time in the process of implementation described in the cases? Which interference?
2. Is it possible to identify the behavior of the organization within a space of possibilities (or attractor) generated by the combination structure-cognition?
3. How has the ERP system implementation changed the attractor of the organization?
4. Is there a relation between the organizational attractor and the three approaches of change – strategic, operational and learning?
5. Is it possible to identify if, before the deployment of the system, the organization had reached its limit of complexity?
6. Is it possible to identify the four phases (potential, vulnerability, uncertainty and testing) through which the system passes to change its level of complexity?
7. Are there indications of organizational maturity?

From the 29 cases analyzed, 12 of them presented enough details to respond to all questions. The other 17 could only be analyzed from the perspective of structural and cognitive subsystems. Tables 2 and 3 show, respectively, the references of the cases analyzed only from the structural/cognitive perspective and the cases completely analyzed. Cases in complete analysis could respond to all 13 questions presented above. This paper presents case analysis interpretation results.

Table 2 - Cases analyzed from structural and cognitive aspects

Cases Authors
Barker & Frolick (2003)
Cowan & Eder (2003)
Dávalos & Mülbert (2002)
Dias et al. (2003)
Hirt & Swanson (1999)
Jesus & Salles (2002)
Lima et al. (2005)
Mendes & Escrivão Filho (2002)
Oliveira & Ramos (2002)
Ozaki & Vidal (2003)
Paper & Tingey (2003)
Ramos & Miranda (2003)
Salazar & Soares (2005)
Santos et al. (sd)
Souza (2000) – Case 7
Zanquetto Filho et al. (2003)
Voordijk et al. (2003)

Table 3 - Cases analyzed from structural/cognitive and dynamics of change /evolutional aspects

Cases Authors
Al-Mashari & Al-Mudimigh (2003)
Edwards & Humphries (2005)
Kansal (2006)

McAdam & Galloway (2005)
Molla & Bhalla (2006)
Souza (2000) – Case 1
Souza (2000) – Case 2
Souza (2000) – Case 3
Souza (2000) – Case 4
Souza (2000) – Case 5
Souza (2000) – Case 6
Souza (2000) – Case 8

Identification of Structural and Cognition Aspects

Action elements and behavior elements identified in each case where grouped together. The resulting groups abstracted implementation details and enabled the identification of patterns of occurrence throughout all the cases. In order to identify the relationship between actions and behaviors, from a structural and cognitive point of view, it was necessary to examine ways in which some elements occur in relation to others. Then, all groups of actions and behaviors identified *after* ERP implementation were related to actions and behaviors identified *before* and *during* ERP implementation.

For example, among the 23 cases that received improvements in production processes, it was identified that 13 had made investments in human resources, 13 had problems with users, 15 saw changes in the mental models. “Improvements in production processes”, and “Problems with users” were groups of behaviors identified in the cases, and “Investments in human resources” was a group of actions identified in the cases.

The intent of this analysis was to identify whether there is any indication that the actions and behaviors in structural and cognitive subsystems can lead to other behaviors. It is not the intention of this study to list ERP implementation best practices, nor to conclude what should be done to achieve success or not with the deployment. The goal was to contribute to the understanding of this process by identifying if there is a tendency where actions and behaviors of the subsystems are agents of the emergence of other behaviors, according to the classification proposed by the model.

From this point of view it was possible to identify that the lack of investments in cognitive subsystem may generate behaviors in the structural subsystem. And changes in the structural subsystem allow the emergence of new behaviors in the cognitive subsystem. Behaviors and actions in both subsystems seem to be closely related, but because we consider complex organization systems and a number of feedback loops happen simultaneously, it is not possible to predict all the cause-effect relationships in the subsystems.

Identification of the Dynamics of Change and Evolution

When the cases were analyzed from an evolution and change point of view, only 12 of them had enough details to respond to the questions. Table 4 presents these case analysis summaries. The cases examined showed that the time and environment generate the need for ERP systems implementations in some of the cases. The two elements have been identified in only three of the cases. The time appeared alone, interfering in five of the cases, and in four of them it was not possible to identify the influence of any of the two. When we say that time interfered, we mean that a situation that was generated over time created the need for the new system (for example, obsolete processes and technology); and when we say that the environment interfered, we mean that market conditions (for example, concurrence, and profit increase needs) influenced the need for a new information system.

The behavior appeared as emerging from the configuration structure-cognition in eight of the cases, confirming the proposal of the model. This behavior seemed to belong to the organizational attractor proposed in the model in all cases. It was only possible to identify that the implementation enabled the change of position of behavior attractor in three cases. It generated a new set of possible answers to the environment and a new level of complexity to the organization. And, therefore, there were only three cases that reached a strategic change with the deployment, achieving competitive advantages by those new possible responses to the environment.

Table 4 - Summary of the analysis in the 12 cases that presented enough details about dynamics of change and evolutional aspects

Case	Environment/ Time	Behavior as a function of structure/cognition	Behavior attractor position change	Change Type	Complexity Limit was reached before change	Transition phases occurred successfully	Observations about system maturity
Al-Mashari & Al-Mudimigh (2003)	Yes	Yes	No	Learning	Yes	No	*No data*
Edwards & Humphries (2005)	Just Time	*No data*	No	Learning	Yes	No	*No data*
Kansal (2006)	Yes	Yes	Yes	Strategic	Yes	Yes	Maturity growth
McAdam & Galloway (2005)	Just time	*No data*	No	Operational and Learning	No	No	Company was already mature
Molla & Bhalla (2006)	Yes	Yes	Yes	Strategic	Yes	Yes	Maturity growth
Souza (2000) – Case 1	Just Time	*No data*	No	Operational	No	Yes	Company was already mature
Souza (2000) – Case 2	No	Yes	No	Operational	No	No	*No data*
Souza (2000) – Case 3	No	Yes	No	Operational and Learning	No	No	*No data*
Souza (2000) – Case 4	Just Time	Yes	Yes	Strategic	Partial	Yes	Company was already mature
Souza (2000) – Case 5	Just Time	Yes	No	Operational and Learning	Partial	Yes	Company was already mature
Souza (2000) – Case 6	No	*No data*	No	Operational and Learning	No	Yes	Company was already mature
Souza (2000) – Case 8	No	Yes	No	Operational and Learning	Partial	No	Maturity growth

The other nine cases showed no change of the position of the attractor of behavior. Obviously, system behavior has changed with the deployment because, as seen, the change in the configuration structure-cognition allows new behaviors to emerge. However, these new attitudes belonged to the set of possible behaviors the organization already had before the deployment. The new system did not create new possibilities. It was also possible to identify five cases that reached operational change and learning, featuring a repositioning of the behavior within the same attractor. Two of them acheived learning only and in two cases, similarly, only operational change was acheived.

The model of organizational change presented in this paper states that, before the attractor of behavior changes position, that is, before the organization changes its level of complexity, the system reaches what is called a limit of complexity, characterized by crises and instability. In this limit, the system no longer responds to the environment the way it needs to survive. Of the twelve cases examined, prior to deployment, only a third of them had reached this limit of complexity. Three of them had some characteristics that led to a limit of complexity, but had not yet had crises in the system. Finally, five cases did not have the characteristics of limit of complexity before deployment.

It was also stated in the model of organizational change that the transition to a new level of complexity is characterized by four phases: potential, vulnerability, uncertainty and testing; and that to achieve the new limit of complexity and acquire innovation with change, the system must successfully go through the four stages. It was possible to identify each of these stages in the process of implementation of the ERP system and check if the change had gone through the four phases or not. In half of the cases the system did not make a complete four-stage transition and in the other half, the four stages were completely done.

The identification of factors related to organizational maturity in the process of implementation was limited due to the low amount of available information in the case studies. With the available data, it was possible to achieve some conclusions in eight of the twelve cases. Of these eight, only three showed increased organizational maturity with the deployment. And in five of them there was indication that the organization was already in a state of maturity before implementation.

Some conclusions can be made analyzing the relationship between the occurrence of these twelve cases detailed facts. In all cases, where both the environment and time created the need for ERP system implementation, organizations showed characteristics that they had reached the limit of complexity. In cases where only the time was identified, only one of the cases stated limit of complexity. And in cases where none appeared described, the limit of complexity was not identified. This is an indication that the environment acts on the structural and cognitive subsystems, as suggested by the model, causing instability and, over time, crises.

Another relationship that could be identified was the occurrence of a change of attractor, with the limit of complexity and with the stages of transition. Of the three cases where there was an attractor change after implementation, the organization had achieved, wholly or partly, the limit of complexity before implementation, and all the stages of transition occurred successfully. This fact gives an indication that, as proposed by the model, it is really necessary to move though the stages of potential, vulnerability,

uncertainty and test to enable the change of the level of complexity. Confirming this statement, from the nine cases in which there was no change of attractor position, five cases had not reached the limit of complexity and in only three of them the stages of transition occurred successfully. Precisely in these three cases the organization had been identified as mature before deployment.

This finding confirms that to reach a new level of complexity, it is really necessary to go through the stages of transition. Organizations that went through the four stages and did not change the level of complexity have shown that they already had adequate responses about the environment, were mature, and did not require a new set of behaviors to generate new answers. Wherever the transition was not successful, the study showed that the limit of complexity had not been reached (or was occurring partially) before the deployment. In all these cases, one of the situations happened: or the organization was already mature, or no information was given. This may be an indication that, for an organization to reach a new level of complexity, the limit of complexity of the current attractor is necessary to generate a real potential for change, the four stages of transition to occur, and finally to install the new level of complexity.

The study did not identify cases where the level of complexity was changed and reduced the maturity of the organization. In other words, it generated a set of behaviors that was not appropriate to the environment). If a long term study were done after the ERP systems implementation, it would be possible to identify for sure if the organization became more mature or if new practices led it to an immature attractor. Table 5 shows the main conclusions reached from the case analysis.

Table 5 - Main conclusions in cases analysis

Structural and Cognitive Subsystems	Dynamics of Change and Evolution
- Lack of investments in the cognitive subsystem may generate behaviors in the structural subsystem;	- Time and/or environment may cause crisis and, then, generate the need of ERP systems implementations;
	- Behavior appeared as emerging from the configuration structure-cognition, belonging to an organizational attractor;
- Changes in the structural subsystem allow the emergence of new behaviors in the cognitive subsystem;	- Some ERP systems implementations enable the change of position of behavior attractor (or level of complexity);
	- Some ERP systems implementations generate new behaviors which belonged to the set of possible behaviors the organization already had before deployment, without changing the level of complexity;
- Behaviors and actions in both subsystems seem to be closely related;	- For an organization to reach a new level of complexity, the limit of complexity of the current attractor is necessary to generate real potential for change;
	- Organizations may move through the stages of potential, vulnerability, uncertainty and test to enable the change of level of complexity (and a new set of behaviors);

8 FINAL CONSIDERATIONS

This paper has presented an ERP systems implementation analysis considering the organization as a complex system. To accomplish this analysis, it suggested a general model to represent complex structures and dynamics in organizations, built based on a systemic approach. Twenty nine ERP implementation cases studies were interpreted through elements from the model.

It is possible to conclude that the model was able to describe many of the complex dynamics of change in these twelve cases studied. Contributions point to the identification of the importance of cognitive subsystems in the deployment of ERP systems; to the possibility of the non-existence of a relationship between the structural and cognitive subsystems; to verify the significance of generating potential for the ERP system implementation through the limit of complexity; to the characterization of change in the level of complexity and achievement of strategic change; to the presence of four complex system transitional stages during the deployment; and finally, to the realization that organizational maturity depends on the organizational context and that it only increases with the deployment of ERP if appropriate.

However, the general feeling was that under the structural-cognitive aspect suggested by the general model, few conclusions could be drawn from the cases. A contribution of this analysis was the identification of the elements of each subsystem in the cases and some of its relations, but the study expected to obtain more evidence of the emergence of behaviors from subsystems. A possible reason for this was the amount of data analyzed and the incompleteness of the data. For the conclusions to be more complete, there needs to be more cases or, at least, cases in which all the variables were described.

Therefore, it is possible to suggest some future work to confirm complex structure and dynamics in ERP (or information systems) implementation. It is possible to apply the model through field case studies, monitoring multiple ERP systems implementations which consider the model during the process. The identification of these complex elements may help in understanding how ERP systems should be designed, built and deployed to better fit organizational complex structures and dynamics.

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